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TENTH MONTHLY PROGRESS REPORT ON

DEVELOPMENT AND TESTING OF ELECTROLYTE

MATRIX COMBINATIONS FOR

MERCURY-POTASSIUM FUEL CELL

Tenth Monthly Progress Report,

(12 Sep~~tember~~—12 Oct~~ober~~ 1963)

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(NASA CR-53351;)
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PROGRESS OF WORK DURING REPORTING PERIOD

Progress during the period included testing of two small cells. The tests proved that the composite will perform and survive up to 30 hr operation with use of an amalgam in the anode side. Resistivity values obtained from these runs were not greater than 6 ohm-cm.

Small Cell Testing

The two small cells successfully tested during the period were NASA-IX and NASA-X. Each matrix was fabricated from a 65% electrolyte composite, using a final sift through a 200 mesh screen prior to cold press forming. X-ray examination did not reveal any flaws or suspect flaws. A change in procedure and conditions was incorporated to minimize the severity of the test on the primary specimen, the cell matrix.

Previous tests used a pure K-metal introduced to the cell above the melt point, probably 100-150°C. Two possible problems existed. First, the procedure might give a cooling depression to the matrix as the K-metal entered.

Second, the conditions with the highly active K-metal might cause a weakening of the matrix through mutual solubility between the potassium and the electrolyte. Therefore, the anode material was changed to an amalgam. The new configuration approaches the conditions of the regenerative systems. Studies of the regenerative systems indicate the necessity of a low potassium amalgam in the anode of the cell.

The choice of a 32% molar amalgam was made to gain the highest melt point on the liquid-solid phase diagram. The melt point (approximately 280°C) of the selected amalgam is near the cell operating temperature and serves to automatically release the anode material to the cell at the proper condition. The high melt point also simplifies the amalgam loader design, since a valve is not required to control introduction of the metal. The cell design includes the permanent stainless steel screens used in NASA-VIII.

NASA-IX

The first amalgam cell, NASA-IX, was assembled with a 94.2% theoretical density, 65% electrolyte content matrix. Data from this operation is shown in Table I.

The matrix withstood the Hg head for 35 hr without apparent leakage. The first 2 hr and 45 min was prior to amalgam loading. Actual electrical performance was maintained for 32 hr and 17 min. Charge-discharge cycling was maintained for nearly 18 hr. The resistivity of the cell was computed as near 6 ohm-cm which is higher than anticipated.

Cycling data is given in Table I as the maximum voltage on charge just prior to open circuit switching, and the minimum voltage on discharge just prior to open circuit switching. There was not a continuous current recording; therefore, only spot check current readings are available. The original setting of current remains fairly constant, however.

The NASA-IX cell developed a slight internal current path on the 34th cycle and dropped in performance. After 51 cycles, a continuous charge current was applied in an attempt to bring back the potential. The cell terminal voltage did rise from 0.43 to 0.62 before the internal short predominated and the voltage dropped to near zero.

Posttest failure analysis did not reveal any further evidence than the performance data shows. The amalgam freeze on both sides caused considerable damage to the matrix upon teardown.

One undesirable feature of the assembly was that of the Hg overflow. Early performance of the cell caused amalgam to be dumped away from the cathode side where it could not be recovered for recharge operation. This same opening also caused a distillation action of the Hg and, therefore, depleted the cathode material. There was no absolute measure of the effect this would have on the life of the cell. This condition was corrected by placing a valve in the overflow line prior to operation of cell NASA-X.

NASA-X

Cell NASA-X was assembled with a matrix of 93.1% theoretical density, 65% electrolyte content. Data from this test also is shown in Table I. This cell performed much like NASA-IX except for duration of operation.

A problem with assembly caused the cell halves to close unevenly. The gap at the top of the cell was slightly larger than the gap at the bottom. This did not appear to hinder cell operation, since the Hg-head was maintained for 2 hr and 45 min prior to amalgam loading. Posttest analysis revealed only a possible failure of the seal in the top region. Serration marks are not evident in this region on the anode side when subjected to macroscopic examination.

Study of Table I shows that the cell performed for 8 hr and 40 min before a sudden internal short dropped the potential to zero. The resistivity was again near 6 ohm-cm with one reading close to 5 ohm-cm.

Table I.

Data on composite electrolyte matrix cells.

Cell electrolyte percentage, and date	Time of day	Cell potential V_o* (volts)	Cell voltage under load V_c (volt)	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
NASA-IX	7:30 a.m.				14 (measured)	
65%	10:20	0.036	(Hg added to preheater)			
9-27-63	10:52	0.060	(Hg contact with matrix)			
	11:02	0.060	(Hg full)			
	11:30	—	(Amalgam loader hookup)			
	12:50	0.090	(Heat up amalgam)			
	1:38	0.085	(Amalgam loading)			
	1:38	0.60	(Step rise)			
	1:38:12	0.80				
	1:38:24	0.835				
	1:39	0.87				
	1:40	0.89				
	1:41	0.91				
	1:42	0.92				
	1:44	0.935				
		(Electrically loaded)				
	1:45	0.76	0.53	0.43	0.535	10.7
	2:00	1.00				
	2:26	—	0.53	0.64		
	2:32	—	0.52	0.625		
	2:37	0.80	0.515	0.62	0.46	9.2
	2:44	(Start charge-discharge cycle equipment)				
	3:46	0.70	0.52	0.60	0.30	6.0
	4:35	0.80	0.71	0.30	0.30	6.0
	5:20	0.83	0.97	0.50	0.28	5.6
	Cycle No. 1	(charge)	0.97			
		(discharge)	0.515			
	10		0.91			
			0.48			
	20		0.86			
			0.445			
	30		0.81			
			0.405			
	34		0.79 (internal load)			
			0.36			
	40		0.74			
			0.325			
	45		0.56			
			0.225			
	50		0.47			
			0.18			
	51		0.45			
9-28-63	11:34 a.m.		0.21	0.20		
		(Start charging)		0.62		
	11:49		0.43			
	12:04		0.52			
	12:34		0.59			
	12:49		0.66			
	12:49+		0.62			

Cell electrolyte percentage, and date	Time of day	Cell potential V_o* (volts)	Cell voltage under load V_c (volt)	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
	1:04		0.50			
	1:32		0.43			
	2:02		0.415			
	2:17		0.23	0.20	(Charge rate change)	
	9:55		0.08	0.20		
			(End run)			
NASA-X	8:47	0.076				
65%	9:18	0.105				
10-10-63	11:12	0.037	(Rotate into vertical position)			
	11:20	0.037	(Hg added to preheater)			
	11:50	0.00	(Hg contact with matrix)			
	1:15	0.30	(Charge current momentarily)			
	1:18	0.25				
	1:21	0.20				
	1:24	0.16				
	1:30	0.00	(Attach amalgam loader)			
	1:42	0.09	(Voltage recovery)			
	1:50	0.30	(Charge current momentarily)			
	2:35	0.36	(Amalgam loading)			
	2:35+	0.80				
	2:38	0.94				
	2:41	0.97				
	2:47	0.99				
	2:48	—	0.56	70.60	(Electrical load)	
	2:55	0.69	0.54	0.62	0.242	4.84
	2:56	0.835	(Open circuit recovery)			
	3:00	(Charge-discharge		0.62	(Discharge)	
	310	Cycle)		0.40	(Charge)	
	Cycle No. 1		1.00	(Charge max)		
			0.53	(Discharge min)		
	5		0.995			
		0.68	0.485	0.65	0.30	6.0
	10		0.96			
			0.57			
	15		0.93			
			0.58			
	20		0.915			
			0.58			
	25		0.905			
			0.575			
	30		0.89			
			0.57			
	35		0.88			
			0.565			
	40		0.870			
			0.560			
	11:13 45		0.865			
			0.150	(Shorting during cycle)		
	46		0.25			
			~ 0.0			

COMPOSITE FABRICATION

Two new composite batches, Nos. 114 and 116, were used to fabricate test specimens. Four 2-in. x 1/8-in. specimens were made from batch 114. Two of these matrices were used in cells NASA-IX and X. The materials had been specially prepared using a fine screen (200 mesh) process prior to cold press. This process gives a finer material which packs more uniformly into the cold press die.

Eight specimens were made from batch 116. Two were 4-in. x 1/8-in. disks, the others all 2-in. x 1/8-in. disks. X-ray quality checks show no cracks, although a shadow area of nonuniform density is present in all. All specimens are oversize in thickness and diameter which may indicate a failure to contract properly during bake out.

WORK FOR NEXT PERIOD

A new attempt to fabricate 4-in. x 1/8-in. specimens without apparent X-ray flaws will be made. The specimens will be tested in the new large cell. The large cell design will be fixed and fabrication completed for the tests.

CUMULATIVE MAN MONTHS EXPENDED

	Through 12 October
Research	24.1
Shop	0.8
Materials Laboratory	18.7
Total	43.6

BUDGET

Research	30
Shop	2
Materials Laboratory	17